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The Solar-powered Module Design of Wireless Video Monitoring System

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Abstract

The node power of traditional remote wireless video monitoring is short-lived, strong binding energy and it needs to be replaced frequently. A new independent module of solar-powered was proposed, which combined the solar panel with lead-acid battery. The protection circuit and sunlight detection circuit were designed for the solar power system. The problem of energy consumption was solved by hardware and software design in the power supply system. The experimental results demonstrate the reliability, security and convenience of the solar-powered module. And it is suitable to apply in various rigorous environmental areas.

Keywords-wireless video monitoring; lead-acid battery; solar panel; JN5139

1. Introduction

Remote wireless video monitoring system is available through micro-sensors to perceive, monitor and collect environmental information, and it has a great deal of potentialities in the field of security monitoring, target tracking and object identification. The image acquisition and processing, wireless transmission and image display, encoding and decoding may cause energy consumption. All the energy is derived from the power. Therefore, the power is the key component of the wireless video monitoring system, and the performance of power directly impacts on the development of wireless video technique. The traditional wireless video monitoring system used the rechargeable battery as power equipment, which is short life-cycle. And it requires to be replaced frequently. Therefore, the rechargeable battery is not appropriate for remote, unmanned and rigorous environmental areas.

The power is provided by the solar panel and lead-acid battery. The solar panel collects the energy of sun and transforms it into electric energy, and then stores the electric energy into lead-acid battery. When the battery is discharging, the terminal voltage may reduce gradually and have some influences on data acquisition. In order to collect reliable data, it requires a stable power supply. As to solar panel and

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lead-acid battery, solar energy utilization efficiency has become an important and crucial issue. In order to improve the efficiency, there are several methods: (1) searching for the new materials with high conversion efficiency, (2) using a dynamic tracking system to track the sun's path, and (3) tracking the sunshine using fixed control algorithm[1].T-S fuzzy method[2], which was applied in maximum power tracking, and it achieved good results. However, when the sunlight is varying, the performance may not be stable. In [3], according to the principle of nonlinear dynamics, Yan designed a simple maximum power point tracker (MPPT). Although the dynamic response is fast and the tracking effectiveness is excellent, dynamic algorithm is too complex. In [4], S.W proposed a new viable powering technology, which enhanced the performance of energy harvesting system and kept the power longer. In [5], Trishan discussed several MPPT techniques and methods, then analyzed their pros and cons. In [6], B.J proposed a new design idea of one axis three positions sun tracking photovoltaic module, which has a simple structure and its cost is low. In [7-8], Wang proposed a double-effect energy-saving delay dispatch algorithm, which combined dynamic voltage scaling (DVS) with dynamic power management (DPM). And he also put forward two low-power real-time scheduling algorithms. (1) static scheduling algorithm for low power consumption; (2) dynamic scheduling algorithm for low power consumption.

According to the distribution statistics of annual solar energy, the maximum power point of solar photovoltaic system has a relation with light intensity and temperature. To increase the efficiency and maximize power output from the solar panel, the solar panel needs to be kept aligned with the sun. In this paper, the external hardware circuit of JN5139 was designed firstly, and then the automatic tracking system was devised, which can keep the solar panel aligned with the sun. At last, the protection circuit was designed, which avoided the battery being in the state of over-charging and over-discharging.

2. Remote wireless monitoring system

Based on the video transmission channel, video monitoring system can be divided into wired video monitoring system and wireless video monitoring system. According to the distance between the customer display terminal and the collection terminal, video monitoring system can be divided into remote video monitoring system and on-site video monitoring system. A remote video monitoring system was chosen in this experiment.

According to the system and the load types, the solar-powered module can be divided into grid-based and standalone. The standalone photovoltaic module was applied in this paper. Its structure is shown in Figure 1. The block diagram of remote wireless video monitoring system is shown in Figure2.

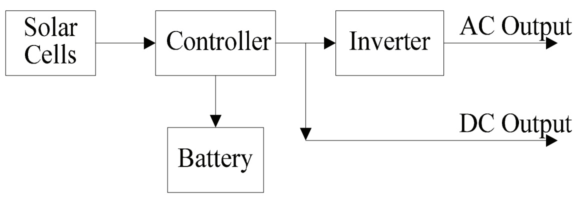

Figure 1. Standalone photovoltaic system

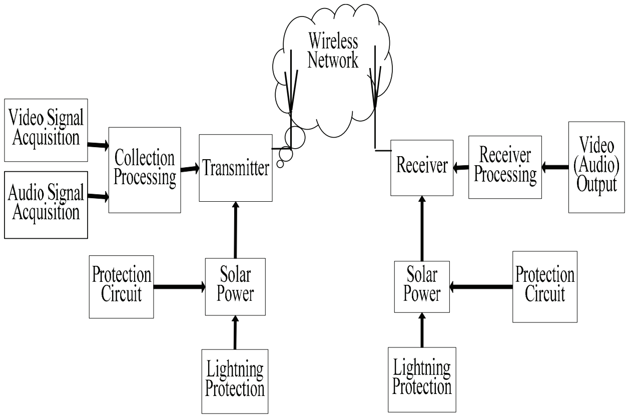

Figure 2 The block diagram of wireless video monitoring system

A standalone photovoltaic module mainly consists of four components: solar panel, regulator, battery and inverter. The function of each part is [9]:

a) Solar Panel is the core and the most valuable part of solar photovoltaic module. It is responsible for collecting the energy of sun and transforming it into electric energy.

b) Solar Controller controls the working state of the whole system, and it plays a role of over-charging and over -discharging protection for a battery.

c) Battery is an energy stored device. It can store the solar energy converted by the solar panel during daylight hours. And the stored energy can provide the given load during periods of low solar irradiation.

d) Converter converts the DC into AC when the voltage type does not match what is required by the load.

3. Solar photovoltaic power supply system

3.1 The equipment

The OV7640 camera of Omnivision is a given load, and it runs on 3.3VDC and 12h per day (6:00-18:00).

3.2 Daily consumption

The actual power consumption can be converted to energy (Wh), which equals to the battery amp-hours (Ah) multiplied by the voltage (V). The no-load current is about 30mA when the equipment is tested in laboratory. And the average current is 40mA when the load is working. So the daily consumption is about 0.48Ah. The actual power consumption for one day is 1.58Wh.

3.3 Battery selection

A 12V sealed maintenance-free lead-acid battery was used in the small solar system, because it can provide the best performance, value and compatibility.

The calculation equation of battery capacity can be expressed as follows [10]:

$$\mathrm{Bc}=\mathrm{C}\times I\times H\times D\times \beta \quad (1)$$

$$C = A \times \delta \tag{2}$$

Where A is the safety factor, A=1.2; acid battery: δ= 1.5, alkaline battery: δ=1.25; I represents the current of the equipment working; H is the hours of the load works per day; D is the consecutive days without sunshine; β is the temperature correction factor (T>0℃; β=1; T>=-10℃, β=1.1; T<= -10℃, β=1.2). The battery storage capacity is 6.65Ah. A 12V/7.5Ah battery was chosen as the energy storage device, the size and weight of the battery is 152* 65 * 100, 2.1Kg.

3.4 Solar panel selection

The polycrystalline silicon, monocrystalline silicon or crystalline silicon is used in the manufacture of solar cells. The monocrystalline silicon solar panel was chosen in the design. It has a high solar cell conversion efficiency (approx.15%) under the un-concentrated sunlight. But the output of the solar panel will reduce by 90% under a shadow or cloud weather.

The power which solar panel generates could be calculated through the following equation [11]:

$$P_s = P_L + P_C = \frac{Ph}{t} + \frac{UBc}{Mt} \tag{3}$$

Where h represents the hours of the equipment operation per day; t is the average sunshine hours of a day; M is the days that the solar panel charges the battery. If it takes 10h to charge the battery per day, it will need about 2 days to charge the battery fully. The power that a solar panel generates is about 3W.

The solar module uses a solar panel (125*125mm^2, 12V/5W, -40℃～+80℃, V_{OC}=21.24V, V_{PP}=17.28V, I_S=0.33A, I_P=0.29A) to generate power for recharging the battery.

4. Hardware design of solar power

4.1 JN5139 module and the external circuit

To meet the long-range and low-power consumption transmission, the JN5139-Z01-M02 module was chosen. It is a high performance, low-power wireless SOC module. The external hardware circuit diagram of JN5139 is shown in Figure 3. It includes solar energy conversion circuit, camera sensor, reset circuit and programming button.

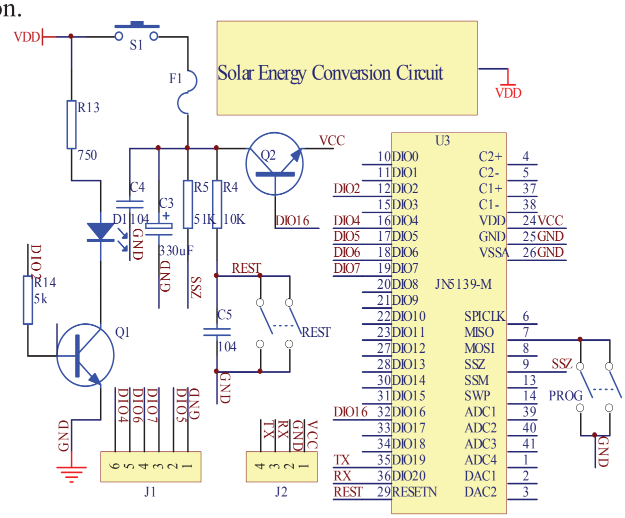

Figure 3 The diagram of JN5139 external circuit

J1 is the data download port, which mainly connects with the PC. J2 is the camera's data port, which is used to connect camera to JN5139. The table of connector is shown in Table 1.

Table 1. The table of connector between Camera and JN5139

Camera	**JN5139**
(2 pin)VCC	(24 pin)VDD
(3 pin)GND	(25pin)GND
(4 pin) TX	(36 pin) RX
(5 pin) RX	(35 pin) TX

4.2 Solar protection circuit

The length of battery life has a relation with the number of charging and discharging, discharging depth, temperature and other conditions. There are two special states (over-charging and over-discharging) during the cyclic charging and discharging of the battery.

When the battery is over-charging, it will result in the oxidation on the positive electrode, a loss of water, and it will be in a danger of explosion. While the battery is working at a lower state of discharging, it will result in deterioration of the battery. So the over-charging and over-discharging will reduce the effective capacity of the battery.

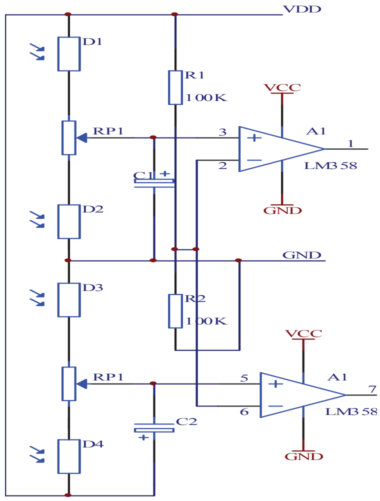

Figure 4 The circuit of solar auto-tracking detection

So as to ensure to maximize power output of the solar panel and increase the efficiency, we designed a solar auto-tracking detection circuit, which is shown in Figure 4. Photosensitive resistance D1 is the pull-up bias resistance of the comparator, which is used to detect the sunlight. D2 is the pull-down bias resistor, which is used to detect the environmental illumination. The voltage comparator is composed of LM358 and R1, R2. And the reference voltage is about half of VDD (+12V). Photosensitive sensor circuit is composed of D1, D2 and potentiometers RP1. It will compensate automatically according to the surrounding light intensity. If D1 is in the sun, the resistance will decrease. The output voltage may rise as well as cathode voltage of LM358. After the amplifier circuit, it drives motor to run[12].

In order to prolong the utilization life of the battery, over-charging and over-discharging should be avoided. The protection circuit of over-charging and over-discharging is shown in Figure 5.

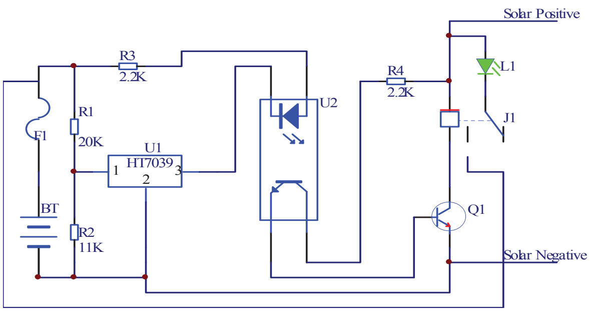

Figure 5 The protection circuit of battery

The HT70XX [13] series are a set of three-terminal low power voltage detectors, which applied CMOS technology. The HT70XX has the function of low power consumption, high-stability reference source and low temperature coefficient.

If V_B (V_B is the positive input of the comparator) is higher than V_{REF}, V_{OUT} will rise. If V_{DD} is decreased caused V_B falls to a value less than V_{REF}, the comparator output will invert from high to low, and V_{OUT} will go low. The functional description diagram is shown in Figure 6. The process diagram of HT7039 is shown in Figure 7. The result diagram of charging and discharging protection circuit is shown in Figure 8.

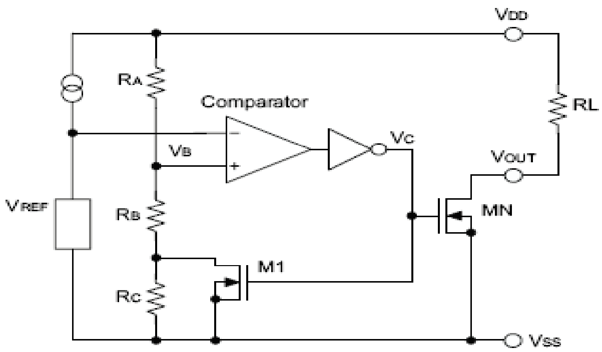

Figure 6 The functional description diagram

The voltage V_{DD} is divided through R_1 and R_2, and compared with the HT7039 internal comparator. If V_{DD}>12.4V, V_{OUT} will go high and the optocoupler will turn off. Then it will stop charging for the battery and L1 will be off. If V_{DD}<11.4V, V_{OUT} will go low and the optocoupler will turn on. Then it will begin charging for the battery and L1 will be on.

$$V_{DET(+)} = \frac{R_A + R_B}{R_B} \times V_{REF} \qquad (4)$$

$$V_{DET(-)} = \frac{R_A + R_B + R_C}{R_B + R_C} \times V_{REF} \quad (5)$$

$$V_{HYS} = V_{DET(+)} - V_{DET(-)} \quad (6)$$

$$\overline{V_{DET}} = \frac{R_1 + R_2}{R_2} V_{DET} \quad (7)$$

$$\overline{V_{HYS}} = \frac{R_1 + R_2}{R_2} V_{HYS} \quad (8)$$

Where V_{DET}=3.9V, V_{HYS}=0.05V, $\overline{V_{DET}}$ =11.7V, $\overline{V_{HYS}}$ =0.15V

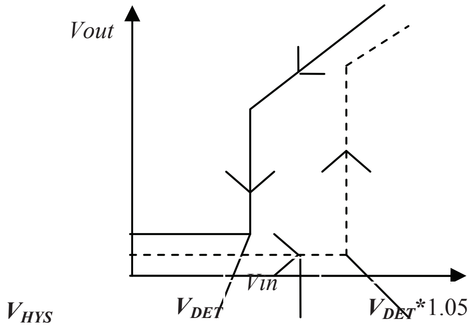

Figure 7 The process diagram of HT7039

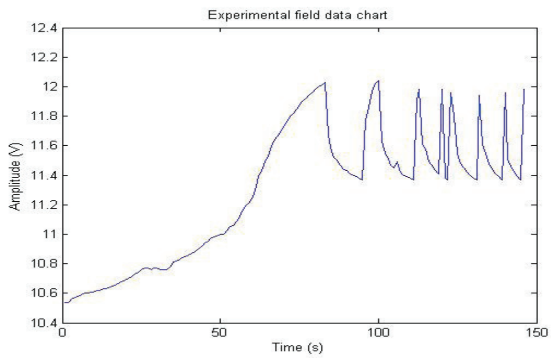

Figure 8 The result of charging and discharging protection circuit

5. The software design of system

The high-power wireless transceiver of JN513X has four modes of operation: transmit mode, receive mode, idle mode and sleep mode. When it powers up, the JN513X automatically goes into idle mode. If data comes in through the port, the module will change into receive mode. When the data is sent, the JN5139 will automatically switch to transmit mode. When a number of different variations come in, the module will switch sleep mode. When the JN5139 is in transmit mode or receive mode, the average current is about 34mA while it is about 0.2μA in the sleep mode. The power consumption of sleep mode is less than the other three modes. When the module does not transmit or receive data, it will shut off the wireless transceiver or switch to sleep mode to reduce power consumption.

In order to reduce the power consumption and extend the life of nodes, we applied with dynamic power management (DPM) technology. DPM makes various parts of the system in energy saving mode. The transceiver enters into a low-power state after the system initialization. In case the interrupt request occurs, CPU will be awakened into activity patterns and implement the interrupt service routine. When the interrupt service routine accomplishes, the system will return to the state before the interruption and continue running in low-power mode.

6. Conclusion

This paper proposed and implemented solar-powered nodes design in wireless sensor network, which was an sustainable energy supply equipment by means of combining a solar panel and battery. The solar panel can automatically track the sun and maximize power output. It can avoid the one-way decreasing of the energy, and has high reliability, low cost and a good practical value. It can be applied in rivers, mountains, islands, forest areas and other rigorous circumstances. In the near future, the accuracy of auto-tracking system would be improved.

Acknowledgment

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